

RESPONSE TO COMMENTS ON
DRAFT ADDENDUM TO THE FEASIBILITY STUDY REPORT FOR PARCEL F
HUNTERS POINT NAVAL SHIPYARD, SAN FRANCISCO, CALIFORNIA

Comments from:

Lily Lee, United States Environmental Protection Agency, December 21, 2016

Section/Page	Comment	Response
Response to General Comment 1c	<p>Currently the response to 1(c) states: "The Navy has acknowledged that additional sediment sampling will be performed in the vicinity of the former Parcel B Piers. The Navy has decided not to revise the text regarding the previous samples not being representative of the sediment under the former Parcel B Piers as this statement would be speculative at this point." Please modify Draft FS Addendum to acknowledge the data gap. For example, here is suggested alternative language: "[p]rior chemical and radiological sampling of sediments is representative of most of the area, except areas under the pier where no samples were collected due to safety concerns."</p>	<p>In response to General Comment 1c, the Navy has added the following text to Section 5.2: "Additional chemical samples will be collected in the vicinity of the former Parcel B piers because these areas were not available for sampling previously. This work will be proposed in a separate work plan, and the results will be provided in an investigation summary report." Decisions about representativeness of the previous data will be made following the proposed investigation.</p>
Response to General Comment 1d	<p>The response partially addresses the comment. Specifically, the response to Part 1(d) states that the Navy, with the Base Realignment and Closure (BRAC) Cleanup Team (BCT) will determine the appropriate method to evaluate the sediment sampling chemical results. We understand that the Navy has a contract to do future sampling and a workplan will be developed. For the record, our understanding is that as part of the future process the Navy should, with BCT involvement, reevaluate the risk assessment if the data from the chemical sampling beneath the piers are substantially different than previously assumed.</p>	<p>Yes, EPA's understanding is correct.</p>
Response to General Comment Number 2 (Original General Comment 6)	<p>The response states that Risk Based Concentrations (RBCs) were calculated using EPA's Preliminary Remediation Goal (PRG) calculator to demonstrate that the Project Action Limits (PAL) established for Parcel F are consistent with the U. S. EPA's Comprehensive Environmental, Compensation, and Liability Act (CERCLA) approach for Superfund remedial radiation risk assessment. This response included Attachment 1, which provided the RBC calculations using formulas from the EPA PRG calculator. The results of the calculations as presented in Table 1 of Attachment 1 indicate that for the subtidal exposure scenario, the RBC values significantly exceed the maximum detection within Parcel F. After review of the calculations performed to estimate the RBCs, the following concerns were identified:</p> <ul style="list-style-type: none"> For the subtidal exposure scenario, the calculations included a gamma shielding factor (GSF) that results in a larger RBC. While Attachment 1 indicates the GSF values were obtained from technical reference documents (Feasibility Study and Data Gap Investigation) specific to Parcel F at Hunter's Point, use of such factors should be reviewed to determine the extent to which they are representative of the specific exposure scenario considered. The small GSFs for subtidal exposures require further justification to establish that they 	<p>(a) The regulatory agencies concurred with the GSFs established for Parcel F during the phase 2a and phase 2b radiological data gap investigations (DGIs) (Battelle and SEA Engineering, Inc., 2013 and ITSI Gilbane & SAIC, 2013). The GSFs were estimated using the Microshield 7 computer model based on a contaminated sediment thickness of one meter and three feet of water overlying the contaminated sediments (i.e., the water provides the shielding). Attachment 1 to these responses to comments provides the modeling for the GSFs (taken from Appendix E of Battelle and SEA Engineering, Inc. [2013]). The conditions assumed to model the GSFs for the subtidal area of Parcel F (i.e., three feet of water overlying a contaminated sediment thickness of one meter) remain appropriate. In fact, the depth of water overlying sediments at Parcel F has been increasing and is likely to continue to increase based on predictions regarding sea level rise (California Climate Change Center, 2009; AECOM, 2016).</p>

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	<p>are appropriate for this application.</p> <ul style="list-style-type: none"> The Distribution Coefficients (K_d values) provided in Attachment 1 are very large, and in some cases do not correspond to other literature values for most of the radionuclides, which results in larger RBC values. For example, the Distribution Coefficient (in Liters per kilogram, L/Kg) for Plutonium-239 is listed as 100,000 L/Kg; however in the EPA document Understanding Variation In Partition Coefficient, K_d, Values, EPA 402-R-99-004B, August 1999 lists a range from 80-2,200 L/Kg, depending on the soil type, oxidation state, pH, and various other factors. These values were obtained from testing fourteen soil types from across seven Department of Energy (DOE) sites in order to provide a representative range of values. While Attachment 1 indicates the K_d values used in the calculations were obtained from site-specific documents, these values require further examination and justification to establish that they are appropriate for this application. The formula used to calculate the RBC for incidental soil ingestion – intertidal and subtidal scenario, uses the formula provided in EPA's PRG calculator; however, the milligrams (mg) of soil ingestion assumed for the child is 200 in the PRG calculator but is listed as half that amount (100 mg) in Equation 2 (Exhibit 1 RBC Equations) of Attachment I. In order to provide the appropriate comparisons in showing consistency with the PRG calculator, the RBC for incidental soil ingestion should be re-calculated using the exposure assumption that the child consumes 200 mg of soil per day. <p>Please revise Attachment 1 to provide justification for the GSFs used for subtidal exposures, the K_d values, and revise the calculations to assume a child consumes 200 mg of soil per day.</p>	<p>(b) The regulatory agencies concurred with the K_d values established for Parcel F during the phase 2a and phase 2b radiological DGIs (Battelle and SEA Engineering, Inc., 2013 and ITSI Gilbane & SAIC, 2013). The K_d values used for the shellfish consumption RBCs are specific to marine environments (i.e., seawater) and are based on assessments and recommendations by the International Atomic Energy Agency (IAEA, 2004). K_d values recommended by USEPA for calculation of radiological PRGs were not used because they are intended for evaluating partitioning from soil to groundwater (i.e., freshwater) and for evaluating partitioning to freshwater fish.</p> <p>USEPA's document <i>Understanding Variation in Partition Coefficient, K_d, Values</i> (USEPA, 1999) includes K_d values from studies specific to marine environments. For example, K_d values cited in USEPA (1999) for plutonium adsorption based on marine studies range from 2,500 to 2,800,000 milliliters per gram (equivalent to liters per kilogram [L/Kg]). The K_d value of 100,000 L/kg used for Plutonium-239 to calculate the shellfish consumption RBC is well within the range of K_d values cited by USEPA (1999) for marine environments.</p> <p>(c) The RBCs for incidental soil ingestion were re-calculated to incorporate the USEPA (2014 and 2016)-recommended incidental soil ingestion rate for children of 200 milligrams per day. Attachment 2 to these responses to comments provides the updated RBC calculations for the Parcel F radionuclides of concern.</p>

References

AECOM. 2016. San Francisco Bay Tidal Datums and Extreme Tides Study. Final Report. February.

Battelle and Sea Engineering, Inc. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2a at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. April.

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California Climate Change Center. 2009. The Impacts of Sea-Level Rise on the California Coast. CEC-200-2009-024-F. May.

International Atomic Energy Agency (IAEA). 2004. Sediment Distribution Coefficients and Concentration Factors for Biota in the Marine Environment. Technical Reports Series No. 422. April.

ITSI Gilbane & SAIC. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2b at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. September.

United States Environmental Protection Agency (USEPA). 1999. Understanding Variation in Partition Coefficient, K_d , Values. Office of Air and Radiation. EPA 402-R-99-004B. August.

United States Environmental Protection Agency (USEPA). 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. Office of Solid Waste and Emergency Management. OSWER Directive 9200.1-120. February 6.

United States Environmental Protection Agency (USEPA). 2016. Preliminary Remediation Goals (PRG) Calculator for Radionuclides. https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search

Attachment 1
Gamma Shielding Factors for Parcel F

Source: Appendix E, Battelle and Sea Engineering, Inc. 2013. *Final Technical Memorandum for Radiological Data Gap Investigation Phase 2a at Parcel F, Hunters Point Naval Shipyard, San Francisco, California*. April.

APPENDIX E
SHIELDING FACTORS

The shielding factors for the subtidal conceptual site model were estimated using the MicroShield 7 computer code (Grove Software, 2006) based on a contaminated sediment thickness of 1 meter and 3 feet of water overlying the sediments, which provided shielding from the radiation emitted from the sediments. The 1-meter thick contaminated sediments were assumed to have infinite lateral extent.

The shielding factors were estimated based on the ratio of the shielded and unshielded dose rates:

$$\text{Shielding Factor} = \frac{\text{Shielded Dose Rate (mSv/hr)}}{\text{Unshielded Dose Rate (mSv/hr)}}$$

The unshielded and shielded dose rates used the rotational geometry effective dose equivalent rate with buildup from the MicroShield output. For the purposes of estimating the shielding factors, the sediments were assumed to be contaminated with 1 pCi/g of Cs-137, Sr-90, U-235, Ra-226, Pu-239, or Co-60. The sediments were assumed to have a density of 1.5 g/cm³. In the case of the unshielded dose rate, the dose rate was determined at 1 meter above the contaminated sediments. Air was assumed to be present between the contaminated sediments and the point at which the dose rate was estimated. In the case of the shielded dose rate, the dose rate was estimated based on 3 feet of water overlying the contaminated sediments and was determined at a distance of 1 meter above the surface of the water. Air was assumed to be present between the surface of the water overlying the contaminated sediments and the point at which the dose rate was estimated.

Table E-1 lists the unshielded and shielded dose rates and the shielding factors for the subtidal conceptual site model.

Table E-1. Unshielded and Shielded Dose Rates and Shielding Factors for the Subtidal Conceptual Site Model

Radionuclide	Unshielded Dose Rate (mSv/hr)	Shielded Dose Rate (mSv/hr)	Shielding Factor
Cs-137	5.074E-6	2.329E-9	4.59E-4
Sr-90	5.947E-14	4.788E-45	8.05E-32
U-235	1.179E-6	3.901E-11	3.31E-5
Ra-226	1.666E-5	5.486E-8	3.29E-3
Pu-239	7.639E-10	4.459E-14	5.84E-5
Co-60	2.374E-5	7.088E-8	2.99E-3

Note: The unshielded and shielded dose rates were based on the rotational geometry effective dose equivalent rate with buildup.

For the revetment, shielding factors were also estimated using the MicroShield 7 computer code. A 1-meter thick layer of contaminated sediment was assumed to be present underneath the revetment. For the purposes of estimating the shielding factors, the sediment was assumed to be contaminated with 1 pCi/g of Cs-137, Sr-90, U-235, Ra-226, Pu-239, or Co-60. The sediment was assumed to have a density of 1.5 g/cm³ and to have infinite lateral extent. The revetment would be constructed from filter fabric, graded crushed rock, and armor stone. The filter fabric layer would not provide significant radiation shielding and was ignored in estimating the shielding factors. The layer of crushed rock was estimated to be about 6 inches to 1 foot thick, and the layer of armor stones was estimated to be about 6 feet thick. An exposed person would be exposed to the contaminated sediments under the revetment, but would be

shielded by the structure of the revetment. For the purposes of estimating the radiation shielding provided by the crushed rock and armor stone, a 2-foot layer of concrete with a density of 2.7 g/cm³ was used. A density of 2.7 g/cm³ is representative of the density of typical stones used to construct revetments. Although the armor stone layer of the revetment would be about 6 feet thick, a 2-foot layer was used in estimating the shielding factors to account for gaps between the armor stones.

In the case of the unshielded dose rate, the dose rate was determined at 1 meter above the contaminated sediments. Air was assumed to be present between the contaminated sediments and the point at which the dose rate was estimated. In the case of the shielded dose rate, the dose rate was estimated based on the 2-foot revetment wall overlying the contaminated sediments and was determined at a distance of 1 meter above the ground surface of the revetment. Air was assumed to be present between the ground surface of the revetment overlying the contaminated sediments and the point at which the dose rate was estimated.

Table E-2 lists the unshielded and shielded dose rates and the shielding factors for the revetment.

The MicroShield output used to estimate the shielding factors are included as Attachment E-1.

Table E-2. Unshielded and Shielded Dose Rates and Shielding Factors for the Revetment

Radionuclide	Unshielded Dose Rate (mSv/hr)	Shielded Dose Rate (mSv/hr)	Shielding Factor
Cs-137	5.074E-6	1.148E-11	2.26E-6
Sr-90	5.947E-14	0.0	0.0
U-235	1.179E-6	5.415E-15	4.59E-9
Ra-226	1.666E-5	2.459E-9	1.48E-4
Pu-239	7.639E-10	8.835E-17	1.16E-7
Co-60	2.374E-5	2.118E-9	8.92E-5

Note: The unshielded and shielded dose rates were based on the rotational geometry effective dose equivalent rate with buildup.

References

Grove Software. 2006. *MicroShield User's Manual*, Version 7. Grove Software, Inc., Lynchburg, VA. October.

ATTACHMENT E-1

MicroShield Output

Unshielded Cs-137 MicroShield Output

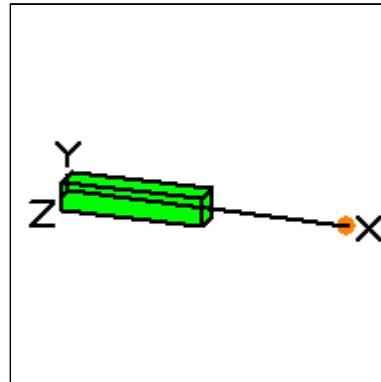
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Cs-137_00_ft_01_m.ms7	May 20, 2010	10:40:28 PM	-01:59:6

Project Info	
Case Title	Cs-137 1 meter air
Description	Cs-137 1 pCi/g sediment 1 meter air shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	200.0 cm (6 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices			
Number of Groups: 25			
Lower Energy Cutoff: 0.015			
Photons < 0.015: Included			
Library: ICRP-38			
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3	
Ba-137m	1.4190e-006	5.2503e-002	
Cs-137	1.5000e-006	5.5500e-002	

Buildup: The material reference is Source			
Integration Parameters			

Results						
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate	
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup	
0.015	4.665e-04	1.709e-07	1.736e-07	1.466e-08	1.489e-08	
0.03	3.179e-03	2.379e-05	2.787e-05	2.358e-07	2.762e-07	
0.04	7.554e-04	1.572e-05	2.252e-05	6.953e-08	9.959e-08	
0.6	4.714e-02	1.110e-01	3.613e-01	2.167e-04	7.053e-04	
Totals	5.154e-02	1.111e-01	3.614e-01	2.170e-04	7.056e-04	

MicroShield 7.02 (05-MSD-7.00-1022)
Battelle
Conversion of calculated exposure in air to dose
FILE: C:\ushield\CaseFiles\Cs-137_00_ft_01_m.ms7
Case Title: Cs-137 1 meter air
This case was run on Thursday, May 20, 2010 at 10:40:28 PM
Dose Point # 1 - (200,0,0) cm

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	1.862e-001	6.037e-001
Photon Energy Fluence Rate	MeV/cm ² /sec	1.111e-001	3.614e-001
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2.170e-004	7.056e-004
Absorbed Dose Rate in Air	mGy/hr	1.895e-006	6.160e-006
"	mrad/hr	1.895e-004	6.160e-004
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2.261e-006	7.353e-006
o Opposed	"	1.787e-006	5.812e-006
o Rotational	"	1.787e-006	5.812e-006
o Isotropic	"	1.580e-006	5.140e-006
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2.395e-006	7.787e-006
o Opposed	"	2.267e-006	7.374e-006
o Rotational	"	2.267e-006	7.374e-006
o Isotropic	"	1.687e-006	5.487e-006
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.993e-006	6.484e-006
o Posterior/Anterior	"	1.746e-006	5.681e-006
o Lateral	"	1.279e-006	4.163e-006
o Rotational	"	1.560e-006	5.074e-006
o Isotropic	"	1.320e-006	4.293e-006

3-Foot Water Shielding Cs-137 MicroShield Output

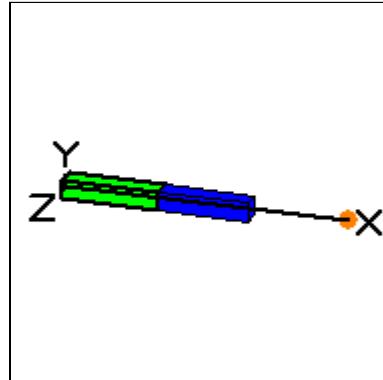
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Cs-137_03_ft_01_m.ms7	May 20, 2010	10:46:10 PM	00:00:00

Project Info	
Case Title	Cs-137 3 foot water
Description	Cs-137 1 pCi/g sediment 3 foot water shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	291.44 cm (9 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	91.44 cm	Water	1
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices			
Number of Groups: 25			
Lower Energy Cutoff: 0.015			
Photons < 0.015: Included			
Library: ICRP-38			
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3	
Ba-137m	1.4190e-006	5.2503e-002	
Cs-137	1.5000e-006	5.5500e-002	

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	4.665e-04	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.03	3.179e-03	1.521e-20	4.497e-19	1.507e-22	4.456e-21
0.04	7.554e-04	8.042e-17	9.523e-15	3.557e-19	4.212e-17
0.6	4.714e-02	3.244e-06	1.659e-04	6.332e-09	3.237e-07
Totals	5.154e-02	3.244e-06	1.659e-04	6.332e-09	3.237e-07

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Cs-137_03_ft_01_m.ms7****Case Title: Cs-137 3 foot water****This case was run on Thursday, May 20, 2010 at 10:46:10 PM****Dose Point # 1 - (291.44,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	5.407e-006	2.764e-004
Photon Energy Fluence Rate	MeV/cm ² /sec	3.244e-006	1.659e-004
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	6.332e-009	3.237e-007
Absorbed Dose Rate in Air	mGy/hr	5.528e-011	2.826e-009
"	mrad/hr	5.528e-009	2.826e-007
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.598e-011	3.374e-009
o Opposed	"	5.216e-011	2.667e-009
o Rotational	"	5.216e-011	2.667e-009
o Isotropic	"	4.613e-011	2.358e-009
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.987e-011	3.573e-009
o Opposed	"	6.618e-011	3.383e-009
o Rotational	"	6.618e-011	3.383e-009
o Isotropic	"	4.924e-011	2.518e-009
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	5.820e-011	2.975e-009
o Posterior/Anterior	"	5.099e-011	2.607e-009
o Lateral	"	3.737e-011	1.911e-009
o Rotational	"	4.554e-011	2.329e-009
o Isotropic	"	3.854e-011	1.970e-009



2-Foot Stone Revetment Shielding Cs-137 MicroShield Output

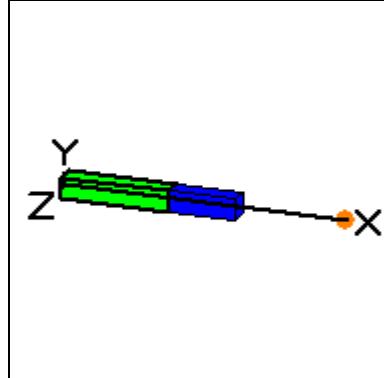
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Cs-137_02_ft_01_m.ms7	May 20, 2010	10:44:42 PM	-01:59:6

Project Info	
Case Title	Cs-137 2 foot stone
Description	Cs-137 1 pCi/g sediment 2 foot armor stone shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	260.96 cm (8 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	60.96 cm	Concrete	2.7
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices			
Number of Groups: 25			
Lower Energy Cutoff: 0.015			
Photons < 0.015: Included			
Library: ICRP-38			
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3	
Ba-137m	1.4190e-006	5.2503e-002	
Cs-137	1.5000e-006	5.5500e-002	

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	4.665e-04	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.03	3.179e-03	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.04	7.554e-04	4.297e-48	4.297e-48	1.901e-50	1.901e-50
0.6	4.714e-02	1.299e-08	8.174e-07	2.535e-11	1.596e-09
Totals	5.154e-02	1.299e-08	8.174e-07	2.535e-11	1.596e-09

MicroShield 7.02 (05-MSD-7.00-1022)
Battelle
Conversion of calculated exposure in air to dose
FILE: C:\ushield\CaseFiles\Cs-137_02_ft_01_m.ms7
Case Title: Cs-137 2 foot stone
This case was run on Thursday, May 20, 2010 at 10:44:42 PM
Dose Point # 1 - (260.96,0,0) cm

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	2.165e-008	1.362e-006
Photon Energy Fluence Rate	MeV/cm ² /sec	1.299e-008	8.174e-007
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2.535e-011	1.596e-009
Absorbed Dose Rate in Air	mGy/hr	2.213e-013	1.393e-011
"	mrad/hr	2.213e-011	1.393e-009
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2.642e-013	1.663e-011
o Opposed	"	2.089e-013	1.314e-011
o Rotational	"	2.089e-013	1.314e-011
o Isotropic	"	1.847e-013	1.162e-011
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2.798e-013	1.761e-011
o Opposed	"	2.650e-013	1.668e-011
o Rotational	"	2.650e-013	1.668e-011
o Isotropic	"	1.972e-013	1.241e-011
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2.330e-013	1.466e-011
o Posterior/Anterior	"	2.042e-013	1.285e-011
o Lateral	"	1.496e-013	9.417e-012
o Rotational	"	1.824e-013	1.148e-011
o Isotropic	"	1.543e-013	9.711e-012



Unshielded Sr-90 MicroShield Output

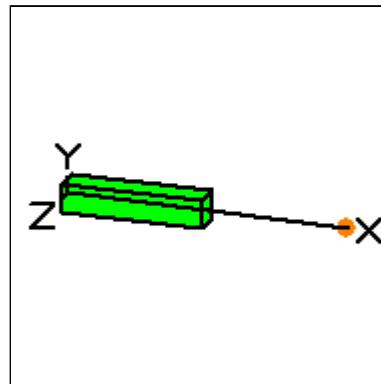
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Sr-90_00_ft_01_m.ms7	May 20, 2010	11:06:07 PM	00:00:00

Project Info	
Case Title	Sr-90 1 meter air
Description	Sr-90 1 pCi/g sediment 1 meter air shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	200.0 cm (6 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices Number of Groups: 25 Lower Energy Cutoff: 0.015 Photons < 0.015: Included Library: ICRP-38			
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3	
Sr-90	1.5000e-006	5.5500e-002	
Y-90	1.5000e-006	5.5500e-002	

Buildup: The material reference is Source Integration Parameters	

Results						
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate	
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup	
0.015	5.122e-06	1.877e-09	1.907e-09	1.610e-10	1.635e-10	
0.02	9.229e-07	1.306e-09	1.363e-09	4.524e-11	4.721e-11	
Totals	6.045e-06	3.183e-09	3.269e-09	2.062e-10	2.107e-10	

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Sr-90_00_ft_01_m.ms7****Case Title: Sr-90 1 meter air****This case was run on Thursday, May 20, 2010 at 11:06:07 PM****Dose Point # 1 - (200,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	1.904e-007	1.952e-007
Photon Energy Fluence Rate	MeV/cm ² /sec	3.183e-009	3.269e-009
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2.062e-010	2.107e-010
Absorbed Dose Rate in Air	mGy/hr	1.800e-012	1.840e-012
"	mrad/hr	1.800e-010	1.840e-010
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.195e-013	6.359e-013
o Opposed	"	3.177e-013	3.263e-013
o Rotational	"	1.886e-013	1.939e-013
o Isotropic	"	1.432e-013	1.474e-013
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.774e-012	1.813e-012
o Opposed	"	9.585e-013	9.805e-013
o Rotational	"	8.974e-013	9.183e-013
o Isotropic	"	8.498e-013	8.689e-013
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.267e-013	1.302e-013
o Posterior/Anterior	"	3.437e-014	3.548e-014
o Lateral	"	2.641e-014	2.714e-014
o Rotational	"	5.784e-014	5.947e-014
o Isotropic	"	4.711e-014	4.845e-014



3-Foot Water Shielding Sr-90 MicroShield Output

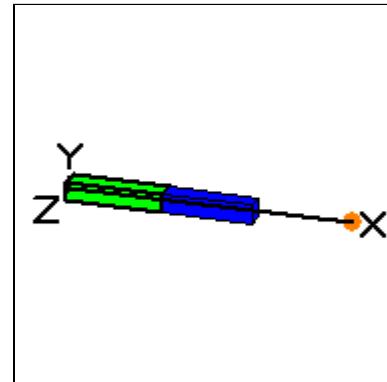
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Sr-90_03_ft_01_m.ms7	May 20, 2010	11:08:43 PM	-01:59:6

Project Info	
Case Title	Sr-90 3 foot water
Description	Sr-90 1 pCi/g sediment 3 foot water shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	291.44 cm (9 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	91.44 cm	Water	1
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Sr-90	1.5000e-006	5.5500e-002
Y-90	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	5.122e-06	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.02	9.229e-07	3.555e-41	2.418e-40	1.231e-42	8.376e-42
Totals	6.045e-06	3.555e-41	2.418e-40	1.231e-42	8.376e-42

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Sr-90_03_ft_01_m.ms7****Case Title: Sr-90 3 foot water****This case was run on Thursday, May 20, 2010 at 11:08:43 PM****Dose Point # 1 - (291.44,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	1.777e-039	1.209e-038
Photon Energy Fluence Rate	MeV/cm ² /sec	3.555e-041	2.418e-040
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.231e-042	8.376e-042
Absorbed Dose Rate in Air	mGy/hr	1.075e-044	7.312e-044
"	mrad/hr	1.075e-042	7.312e-042
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.527e-045	4.440e-044
o Opposed	"	3.475e-045	2.363e-044
o Rotational	"	2.278e-045	1.550e-044
o Isotropic	"	1.875e-045	1.275e-044
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.101e-044	7.487e-044
o Opposed	"	6.719e-045	4.570e-044
o Rotational	"	6.527e-045	4.440e-044
o Isotropic	"	5.477e-045	3.726e-044
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.523e-045	1.036e-044
o Posterior/Anterior	"	5.554e-046	3.778e-045
o Lateral	"	3.142e-046	2.137e-045
o Rotational	"	7.039e-046	4.788e-045
o Isotropic	"	5.836e-046	3.970e-045



2-Foot Stone Revetment Shielding Sr-90 MicroShield Output

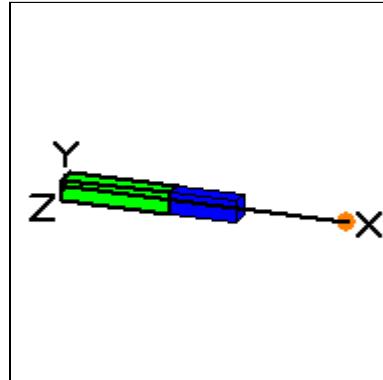
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Sr-90_02_ft_01_m.ms7	May 20, 2010	11:07:14 PM	00:00:00

Project Info	
Case Title	Sr-90 2 foot stone
Description	Sr-90 1 pCi/g sediment 2 foot armor stone shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	260.96 cm (8 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	60.96 cm	Concrete	2.7
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Sr-90	1.5000e-006	5.5500e-002
Y-90	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	5.122e-06	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.02	9.229e-07	0.000e+00	0.000e+00	0.000e+00	0.000e+00
Totals	6.045e-06	0.000e+00	0.000e+00	0.000e+00	0.000e+00

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Sr-90_02_ft_01_m.ms7****Case Title: Sr-90 2 foot stone****This case was run on Thursday, May 20, 2010 at 11:07:14 PM****Dose Point # 1 - (260.96,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	0.000e+000	0.000e+000
Photon Energy Fluence Rate	MeV/cm ² /sec	0.000e+000	0.000e+000
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	0.000e+000	0.000e+000
Absorbed Dose Rate in Air	mGy/hr	0.000e+000	0.000e+000
"	mrad/hr	0.000e+000	0.000e+000
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	0.000e+000	0.000e+000
o Opposed	"	0.000e+000	0.000e+000
o Rotational	"	0.000e+000	0.000e+000
o Isotropic	"	0.000e+000	0.000e+000
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	0.000e+000	0.000e+000
o Opposed	"	0.000e+000	0.000e+000
o Rotational	"	0.000e+000	0.000e+000
o Isotropic	"	0.000e+000	0.000e+000
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	0.000e+000	0.000e+000
o Posterior/Anterior	"	0.000e+000	0.000e+000
o Lateral	"	0.000e+000	0.000e+000
o Rotational	"	0.000e+000	0.000e+000
o Isotropic	"	0.000e+000	0.000e+000



Unshielded U-235 MicroShield Output

MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

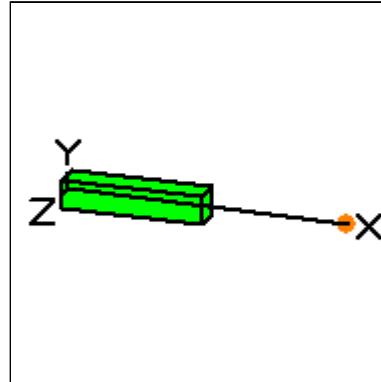
Filename	Run Date	Run Time	Duration
U-235_00_ft_01_m.ms7	May 20, 2010	11:10:42 PM	00:00:00

Project Info

Case Title	U-235 1 meter air
Description	U-235 1 pCi/g sediment 1 meter air shield
Geometry	16 - Infinite Slab

Source Dimensions

Thickness	100.0 cm (3 ft 3.4 in)
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**Dose Points**

A	X	Y	Z
#1	200.0 cm (6 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices

Number of Groups: 25

Lower Energy Cutoff: 0.015

Photons < 0.015: Included

Library: ICRP-38

Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Th-231	1.5000e-006	5.5500e-002
U-235	1.5000e-006	5.5500e-002

Buildup: The material reference is Source**Integration Parameters****Results**

Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	4.927e-02	1.805e-05	1.834e-05	1.548e-06	1.573e-06
0.02	6.255e-03	8.853e-06	9.237e-06	3.067e-07	3.200e-07
0.03	8.223e-03	6.153e-05	7.208e-05	6.098e-07	7.144e-07
0.04	7.132e-05	1.484e-06	2.126e-06	6.565e-09	9.403e-09
0.05	6.839e-05	2.812e-06	4.701e-06	7.490e-09	1.252e-08
0.06	3.055e-04	2.018e-05	4.324e-05	4.009e-08	8.589e-08
0.08	6.958e-03	8.477e-04	2.196e-03	1.341e-06	3.476e-06
0.1	6.648e-03	1.196e-03	3.892e-03	1.830e-06	5.955e-06

0.15	8.785e-03	2.911e-03	1.186e-02	4.793e-06	1.952e-05
0.2	3.393e-02	1.685e-02	7.125e-02	2.975e-05	1.258e-04
0.3	7.344e-05	6.426e-05	2.622e-04	1.219e-07	4.974e-07
0.4	4.832e-05	6.349e-05	2.393e-04	1.237e-07	4.663e-07
0.5	4.662e-06	8.433e-06	2.949e-05	1.655e-08	5.788e-08
0.8	5.550e-07	1.996e-06	5.689e-06	3.796e-09	1.082e-08
Totals	1.206e-01	2.206e-02	8.988e-02	4.050e-05	1.585e-04

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\U-235_00_ft_01_m.ms7****Case Title: U-235 1 meter air****This case was run on Thursday, May 20, 2010 at 11:10:42 PM****Dose Point # 1 - (200,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	1.308e-001	5.082e-001
Photon Energy Fluence Rate	MeV/cm ² /sec	2.206e-002	8.988e-002
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	4.050e-005	1.585e-004
Absorbed Dose Rate in Air	mGy/hr	3.535e-007	1.383e-006
"	mrad/hr	3.535e-005	1.383e-004
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4.854e-007	1.945e-006
o Opposed	"	3.041e-007	1.229e-006
o Rotational	"	3.022e-007	1.226e-006
o Isotropic	"	2.789e-007	1.130e-006
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4.963e-007	1.956e-006
o Opposed	"	4.296e-007	1.721e-006
o Rotational	"	4.291e-007	1.720e-006
o Isotropic	"	3.068e-007	1.223e-006
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	4.136e-007	1.676e-006
o Posterior/Anterior	"	3.348e-007	1.364e-006
o Lateral	"	2.185e-007	8.915e-007
o Rotational	"	2.896e-007	1.179e-006
o Isotropic	"	2.377e-007	9.677e-007



3-Foot Water Shielding U-235 MicroShield Output

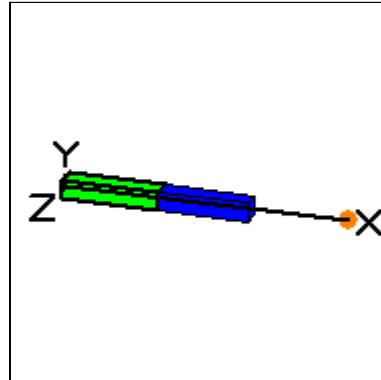
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
U-235_03_ft_01_m.ms7	May 20, 2010	11:13:08 PM	00:00:00

Project Info	
Case Title	U-235 3 foot water
Description	U-235 1 pCi/g sediment 3 foot water shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	291.44 cm (9 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	91.44 cm	Water	1
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Th-231	1.5000e-006	5.5500e-002
U-235	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	4.927e-02	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.02	6.255e-03	2.409e-37	1.639e-36	8.346e-39	5.677e-38
0.03	8.223e-03	3.933e-20	1.163e-18	3.898e-22	1.153e-20
0.04	7.132e-05	7.593e-18	8.991e-16	3.358e-20	3.977e-18
0.05	6.839e-05	4.130e-16	1.562e-13	1.100e-18	4.160e-16
0.06	3.055e-04	1.593e-14	1.151e-11	3.165e-17	2.285e-14
0.08	6.958e-03	4.026e-12	5.310e-09	6.371e-15	8.403e-12

0.1	6.648e-03	1.670e-11	2.325e-08	2.555e-14	3.557e-11
0.15	8.785e-03	2.412e-10	2.043e-07	3.971e-13	3.364e-10
0.2	3.393e-02	4.900e-09	2.654e-06	8.648e-12	4.685e-09
0.3	7.344e-05	1.068e-10	2.358e-08	2.026e-13	4.474e-11
0.4	4.832e-05	3.591e-10	4.143e-08	6.996e-13	8.071e-11
0.5	4.662e-06	1.194e-10	8.592e-09	2.344e-13	1.687e-11
0.8	5.550e-07	1.745e-10	5.191e-09	3.320e-13	9.874e-12
Totals	1.206e-01	5.922e-09	2.966e-06	1.055e-11	5.218e-09

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\U-235_03_ft_01_m.ms7****Case Title: U-235 3 foot water****This case was run on Thursday, May 20, 2010 at 11:13:08 PM****Dose Point # 1 - (291.44,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	2.804e-008	1.514e-005
Photon Energy Fluence Rate	MeV/cm ² /sec	5.922e-009	2.966e-006
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.055e-011	5.218e-009
Absorbed Dose Rate in Air	mGy/hr	9.207e-014	4.555e-011
"	mrad/hr	9.207e-012	4.555e-009
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.265e-013	6.356e-011
o Opposed	"	8.304e-014	4.088e-011
o Rotational	"	8.303e-014	4.088e-011
o Isotropic	"	7.582e-014	3.750e-011
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.271e-013	6.361e-011
o Opposed	"	1.148e-013	5.698e-011
o Rotational	"	1.148e-013	5.698e-011
o Isotropic	"	8.155e-014	4.036e-011
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.096e-013	5.503e-011
o Posterior/Anterior	"	9.030e-014	4.506e-011
o Lateral	"	6.016e-014	2.969e-011
o Rotational	"	7.840e-014	3.901e-011
o Isotropic	"	6.473e-014	3.211e-011



2-Foot Stone Revetment Shielding U-235 MicroShield Output

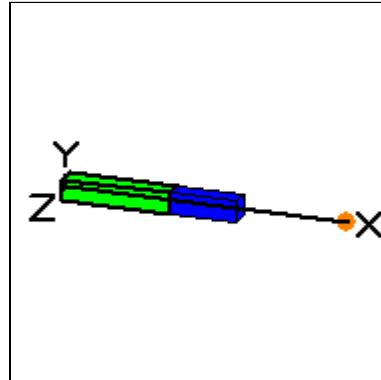
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
U-235_02_ft_01_m.ms7	May 20, 2010	11:11:46 PM	00:00:00

Project Info	
Case Title	U-235 2 foot stone
Description	U-235 1 pCi/g sediment 2 foot armor stone shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	260.96 cm (8 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	60.96 cm	Concrete	2.7
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Th-231	1.5000e-006	5.5500e-002
U-235	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	4.927e-02	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.02	6.255e-03	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.03	8.223e-03	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.04	7.132e-05	4.058e-49	4.058e-49	1.795e-51	1.795e-51
0.05	6.839e-05	4.070e-34	6.927e-33	1.084e-36	1.845e-35
0.06	3.055e-04	1.083e-26	4.312e-25	2.152e-29	8.565e-28
0.08	6.958e-03	1.293e-19	8.553e-18	2.046e-22	1.353e-20

0.1	6.648e-03	2.900e-17	3.842e-15	4.437e-20	5.878e-18
0.15	8.785e-03	1.275e-14	3.069e-12	2.100e-17	5.054e-15
0.2	3.393e-02	9.362e-13	2.428e-10	1.652e-15	4.285e-13
0.3	7.344e-05	7.513e-14	1.388e-11	1.425e-16	2.633e-14
0.4	4.832e-05	5.417e-13	6.500e-11	1.056e-15	1.266e-13
0.5	4.662e-06	3.124e-13	2.649e-11	6.132e-16	5.199e-14
0.8	5.550e-07	1.319e-12	5.141e-11	2.508e-15	9.779e-14
Totals	1.206e-01	3.197e-12	4.027e-10	5.993e-15	7.363e-13

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\U-235_02_ft_01_m.ms7****Case Title: U-235 2 foot stone****This case was run on Thursday, May 20, 2010 at 11:11:46 PM****Dose Point # 1 - (260.96,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	8.644e-012	1.560e-009
Photon Energy Fluence Rate	MeV/cm ² /sec	3.197e-012	4.027e-010
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	5.993e-015	7.363e-013
Absorbed Dose Rate in Air	mGy/hr	5.232e-017	6.428e-015
"	mrad/hr	5.232e-015	6.428e-013
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.558e-017	8.506e-015
o Opposed	"	4.878e-017	5.875e-015
o Rotational	"	4.878e-017	5.875e-015
o Isotropic	"	4.358e-017	5.310e-015
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.812e-017	8.658e-015
o Opposed	"	6.363e-017	7.939e-015
o Rotational	"	6.363e-017	7.939e-015
o Isotropic	"	4.671e-017	5.702e-015
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	5.749e-017	7.394e-015
o Posterior/Anterior	"	4.947e-017	6.194e-015
o Lateral	"	3.534e-017	4.240e-015
o Rotational	"	4.369e-017	5.415e-015
o Isotropic	"	3.683e-017	4.505e-015



Unshielded Ra-226 MicroShield Output

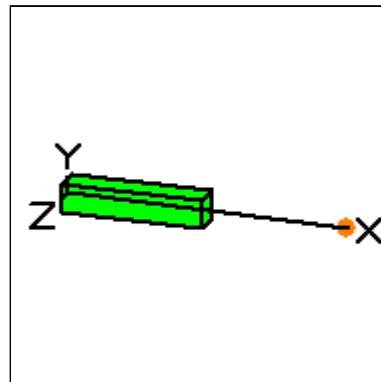
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Ra-226_00_ft_01_m.ms7	May 20, 2010	10:57:03 PM	00:00:00

Project Info	
Case Title	Ra-226 1 meter air
Description	Ra-226 1 pCi/g sediment 1 meter air shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	200.0 cm (6 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices Number of Groups: 25 Lower Energy Cutoff: 0.015 Photons < 0.015: Included Library: ICRP-38			
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3	
At-218	3.0000e-010	1.1100e-005	
Bi-214	1.5000e-006	5.5500e-002	
Pb-214	1.5000e-006	5.5500e-002	
Po-214	1.5000e-006	5.5500e-002	
Po-218	1.5000e-006	5.5500e-002	
Ra-226	1.5000e-006	5.5500e-002	
Rn-222	1.5000e-006	5.5500e-002	

Buildup: The material reference is Source Integration Parameters	
Energy (MeV)	Activity (Photons/sec)

Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	8.111e-03	2.972e-06	3.019e-06	2.549e-07	2.589e-07
0.05	6.118e-04	2.515e-05	4.206e-05	6.701e-08	1.120e-07
0.08	1.352e-02	1.647e-03	4.267e-03	2.606e-06	6.752e-06

0.1	1.374e-04	2.471e-05	8.042e-05	3.780e-08	1.230e-07
0.15	5.456e-05	1.807e-05	7.363e-05	2.976e-08	1.212e-07
0.2	6.005e-03	2.983e-03	1.261e-02	5.265e-06	2.226e-05
0.3	1.152e-02	1.008e-02	4.115e-02	1.913e-05	7.806e-05
0.4	2.120e-02	2.785e-02	1.050e-01	5.426e-05	2.046e-04
0.5	1.157e-03	2.092e-03	7.316e-03	4.106e-06	1.436e-05
0.6	2.695e-02	6.348e-02	2.066e-01	1.239e-04	4.033e-04
0.8	5.433e-03	1.953e-02	5.569e-02	3.716e-05	1.059e-04
1.0	1.569e-02	7.875e-02	2.039e-01	1.452e-04	3.759e-04
1.5	1.070e-02	9.958e-02	2.149e-01	1.675e-04	3.615e-04
2.0	1.533e-02	2.215e-01	4.349e-01	3.426e-04	6.725e-04
3.0	9.446e-05	2.523e-03	4.416e-03	3.423e-06	5.991e-06
Totals	1.365e-01	5.301e-01	1.291e+00	9.055e-04	2.252e-03

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Ra-226_00_ft_01_m.ms7****Case Title: Ra-226 1 meter air****This case was run on Thursday, May 20, 2010 at 10:57:03 PM****Dose Point # 1 - (200,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	5.310e-001	1.513e+000
Photon Energy Fluence Rate	MeV/cm ² /sec	5.301e-001	1.291e+000
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	9.055e-004	2.252e-003
Absorbed Dose Rate in Air	mGy/hr	7.905e-006	1.966e-005
"	mrad/hr	7.905e-004	1.966e-003
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	9.158e-006	2.298e-005
o Opposed	"	7.751e-006	1.913e-005
o Rotational	"	7.750e-006	1.913e-005
o Isotropic	"	6.938e-006	1.710e-005
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	9.635e-006	2.417e-005
o Opposed	"	9.257e-006	2.315e-005
o Rotational	"	9.257e-006	2.315e-005
o Isotropic	"	7.307e-006	1.806e-005
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	8.190e-006	2.049e-005
o Posterior/Anterior	"	7.479e-006	1.854e-005
o Lateral	"	5.916e-006	1.445e-005
o Rotational	"	6.737e-006	1.666e-005
o Isotropic	"	5.937e-006	1.458e-005



3-Foot Water Shielding Ra-226 MicroShield Output

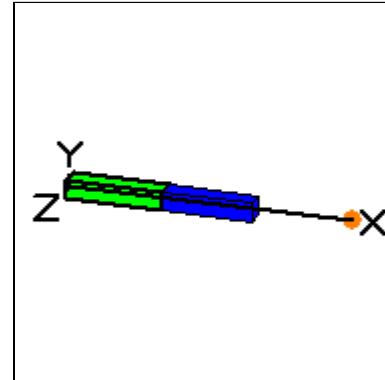
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Ra-226_03_ft_01_m.ms7	May 20, 2010	10:59:26 PM	00:00:00

Project Info	
Case Title	Ra-226 3 foot water
Description	Ra-226 1 pCi/g sediment 3 foot water shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	291.44 cm (9 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	91.44 cm	Water	1
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
At-218	3.0000e-010	1.1100e-005
Bi-214	1.5000e-006	5.5500e-002
Pb-214	1.5000e-006	5.5500e-002
Po-214	1.5000e-006	5.5500e-002
Po-218	1.5000e-006	5.5500e-002
Ra-226	1.5000e-006	5.5500e-002
Rn-222	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	8.111e-03	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.05	6.118e-04	3.694e-15	1.397e-12	9.841e-18	3.721e-15

0.08	1.352e-02	7.822e-12	1.032e-08	1.238e-14	1.633e-11
0.1	1.374e-04	3.451e-13	4.805e-10	5.280e-16	7.351e-13
0.15	5.456e-05	1.498e-12	1.269e-09	2.466e-15	2.089e-12
0.2	6.005e-03	8.673e-10	4.698e-07	1.531e-12	8.292e-10
0.3	1.152e-02	1.676e-08	3.701e-06	3.180e-11	7.020e-09
0.4	2.120e-02	1.575e-07	1.817e-05	3.069e-10	3.540e-08
0.5	1.157e-03	2.962e-08	2.132e-06	5.814e-11	4.184e-09
0.6	2.695e-02	1.855e-06	9.483e-05	3.620e-09	1.851e-07
0.8	5.433e-03	1.709e-06	5.082e-05	3.250e-09	9.665e-08
1.0	1.569e-02	1.547e-05	3.201e-04	2.851e-08	5.900e-07
1.5	1.070e-02	7.610e-05	8.527e-04	1.280e-07	1.435e-06
2.0	1.533e-02	3.991e-04	3.110e-03	6.172e-07	4.810e-06
3.0	9.446e-05	1.289e-05	6.651e-05	1.749e-08	9.023e-08
Totals	1.365e-01	5.074e-04	4.520e-03	7.985e-07	7.254e-06

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Ra-226_03_ft_01_m.ms7****Case Title: Ra-226 3 foot water****This case was run on Thursday, May 20, 2010 at 10:59:26 PM****Dose Point # 1 - (291.44,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	2.758e-004	2.752e-003
Photon Energy Fluence Rate	MeV/cm ² /sec	5.074e-004	4.520e-003
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	7.985e-007	7.254e-006
Absorbed Dose Rate in Air	mGy/hr	6.971e-009	6.333e-008
"	mrad/hr	6.971e-007	6.333e-006
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	7.889e-009	7.187e-008
o Opposed	"	7.015e-009	6.338e-008
o Rotational	"	7.015e-009	6.338e-008
o Isotropic	"	6.323e-009	5.702e-008
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	8.258e-009	7.541e-008
o Opposed	"	8.029e-009	7.316e-008
o Rotational	"	8.029e-009	7.316e-008
o Isotropic	"	6.584e-009	5.954e-008
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	7.123e-009	6.480e-008
o Posterior/Anterior	"	6.681e-009	6.049e-008
o Lateral	"	5.537e-009	4.968e-008
o Rotational	"	6.069e-009	5.486e-008
o Isotropic	"	5.469e-009	4.921e-008



2-Foot Stone Revetment Shielding Ra-226 MicroShield Output

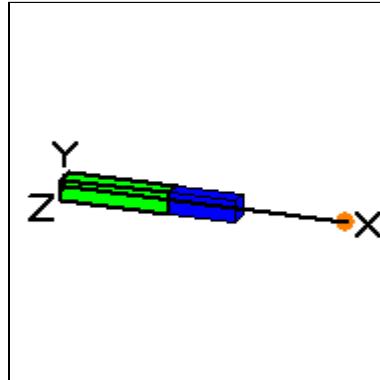
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Ra-226_02_ft_01_m.ms7	May 20, 2010	10:58:22 PM	00:00:00

Project Info	
Case Title	Ra-226 2 foot stone
Description	Ra-226 1 pCi/g sediment 2 foot armor stone shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	260.96 cm (8 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	60.96 cm	Concrete	2.7
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
At-218	3.0000e-010	1.1100e-005
Bi-214	1.5000e-006	5.5500e-002
Pb-214	1.5000e-006	5.5500e-002
Po-214	1.5000e-006	5.5500e-002
Po-218	1.5000e-006	5.5500e-002
Ra-226	1.5000e-006	5.5500e-002
Rn-222	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	8.111e-03	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.05	6.118e-04	3.641e-33	6.196e-32	9.699e-36	1.651e-34

0.08	1.352e-02	2.512e-19	1.662e-17	3.975e-22	2.630e-20
0.1	1.374e-04	5.992e-19	7.939e-17	9.167e-22	1.215e-19
0.15	5.456e-05	7.919e-17	1.906e-14	1.304e-19	3.138e-17
0.2	6.005e-03	1.657e-13	4.297e-11	2.925e-16	7.585e-14
0.3	1.152e-02	1.179e-11	2.178e-09	2.237e-14	4.132e-12
0.4	2.120e-02	2.376e-10	2.851e-08	4.630e-13	5.555e-11
0.5	1.157e-03	7.751e-11	6.571e-09	1.521e-13	1.290e-11
0.6	2.695e-02	7.427e-09	4.674e-07	1.450e-11	9.123e-10
0.8	5.433e-03	1.291e-08	5.033e-07	2.455e-11	9.573e-10
1.0	1.569e-02	1.852e-07	5.037e-06	3.413e-10	9.285e-09
1.5	1.070e-02	1.935e-06	2.879e-05	3.256e-09	4.843e-08
2.0	1.533e-02	1.573e-05	1.655e-04	2.432e-08	2.559e-07
3.0	9.446e-05	8.175e-07	5.672e-06	1.109e-09	7.696e-09
Totals	1.365e-01	1.869e-05	2.060e-04	2.907e-08	3.233e-07

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Ra-226_02_ft_01_m.ms7****Case Title: Ra-226 2 foot stone****This case was run on Thursday, May 20, 2010 at 10:58:22 PM****Dose Point # 1 - (260.96,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	9.642e-006	1.104e-004
Photon Energy Fluence Rate	MeV/cm ² /sec	1.869e-005	2.060e-004
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	2.907e-008	3.233e-007
Absorbed Dose Rate in Air	mGy/hr	2.538e-010	2.822e-009
"	mrad/hr	2.538e-008	2.822e-007
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2.870e-010	3.193e-009
o Opposed	"	2.561e-010	2.842e-009
o Rotational	"	2.561e-010	2.842e-009
o Isotropic	"	2.311e-010	2.562e-009
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	2.999e-010	3.341e-009
o Opposed	"	2.919e-010	3.249e-009
o Rotational	"	2.919e-010	3.249e-009
o Isotropic	"	2.403e-010	2.667e-009
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	2.593e-010	2.883e-009
o Posterior/Anterior	"	2.437e-010	2.706e-009
o Lateral	"	2.029e-010	2.245e-009
o Rotational	"	2.216e-010	2.459e-009
o Isotropic	"	2.001e-010	2.217e-009



Unshielded Pu-239 MicroShield Output

MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

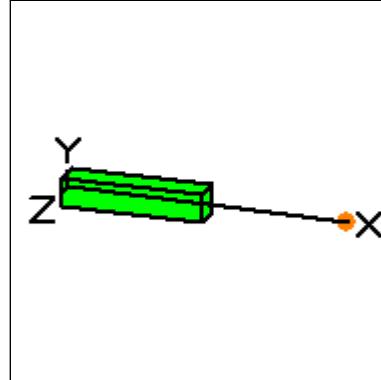
Filename	Run Date	Run Time	Duration
Pu-239_00_ft_01_m.ms7	May 20, 2010	10:48:00 PM	00:00:00

Project Info

Case Title	Pu-239 1 meter air
Description	Pu-239 1 pCi/g sediment 1 meter air shield
Geometry	16 - Infinite Slab

Source Dimensions

Thickness	100.0 cm (3 ft 3.4 in)
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**Dose Points**

A	X	Y	Z
#1	200.0 cm (6 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices

Number of Groups: 25

Lower Energy Cutoff: 0.015

Photons < 0.015: Included

Library: ICRP-38

Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Pu-239	1.5000e-006	5.5500e-002

Buildup: The material reference is Source
Integration Parameters
Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	5.749e-02	2.106e-05	2.140e-05	1.806e-06	1.835e-06
0.02	2.696e-04	3.816e-07	3.982e-07	1.322e-08	1.379e-08
0.03	5.828e-08	4.361e-10	5.108e-10	4.322e-12	5.063e-12
0.04	3.308e-06	6.884e-08	9.860e-08	3.045e-10	4.361e-10
0.05	1.194e-05	4.908e-07	8.206e-07	1.307e-09	2.186e-09
0.06	9.463e-07	6.251e-08	1.339e-07	1.242e-10	2.660e-10
0.08	3.663e-07	4.462e-08	1.156e-07	7.062e-11	1.830e-10
0.1	6.185e-06	1.113e-06	3.621e-06	1.702e-09	5.540e-09
0.15	3.859e-06	1.279e-06	5.208e-06	2.105e-09	8.577e-09

0.2	4.996e-07	2.482e-07	1.049e-06	4.381e-10	1.852e-09
0.3	9.052e-07	7.921e-07	3.232e-06	1.503e-09	6.131e-09
0.4	2.689e-06	3.533e-06	1.332e-05	6.885e-09	2.595e-08
0.5	1.121e-07	2.028e-07	7.091e-07	3.980e-10	1.392e-09
0.6	3.752e-08	8.837e-08	2.876e-07	1.725e-10	5.614e-10
0.8	1.316e-08	4.733e-08	1.349e-07	9.003e-11	2.566e-10
1.0	1.182e-10	5.935e-10	1.537e-09	1.094e-12	2.832e-12
Totals	5.779e-02	2.941e-05	5.053e-05	1.835e-06	1.902e-06

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Pu-239_00_ft_01_m.ms7****Case Title: Pu-239 1 meter air****This case was run on Thursday, May 20, 2010 at 10:48:00 PM****Dose Point # 1 - (200,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	1.469e-003	1.591e-003
Photon Energy Fluence Rate	MeV/cm ² /sec	2.941e-005	5.053e-005
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.835e-006	1.902e-006
Absorbed Dose Rate in Air	mGy/hr	1.602e-008	1.661e-008
"	mrad/hr	1.602e-006	1.661e-006
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	4.514e-009	5.040e-009
o Opposed	"	2.291e-009	2.633e-009
o Rotational	"	1.322e-009	1.648e-009
o Isotropic	"	9.631e-010	1.255e-009
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.567e-008	1.638e-008
o Opposed	"	8.220e-009	8.765e-009
o Rotational	"	7.612e-009	8.146e-009
o Isotropic	"	7.454e-009	7.870e-009
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	9.644e-010	1.369e-009
o Posterior/Anterior	"	2.883e-010	6.145e-010
o Lateral	"	2.541e-010	4.754e-010
o Rotational	"	4.758e-010	7.639e-010
o Isotropic	"	3.848e-010	6.231e-010



3-Foot Water Shielding Pu-239 MicroShield Output

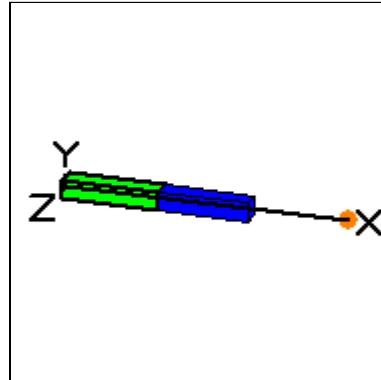
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Pu-239_03_ft_01_m.ms7	May 20, 2010	10:51:39 PM	00:00:00

Project Info	
Case Title	Pu-239 3 foot water
Description	Pu-239 1 pCi/g sediment 3 foot water shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	291.44 cm (9 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	91.44 cm	Water	1
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Pu-239	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results						
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate	
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup	
0.015	5.749e-02	0.000e+00	0.000e+00	0.000e+00	0.000e+00	
0.02	2.696e-04	1.039e-38	7.065e-38	3.598e-40	2.447e-39	
0.03	5.828e-08	2.787e-25	8.242e-24	2.762e-27	8.169e-26	
0.04	3.308e-06	3.522e-19	4.170e-17	1.557e-21	1.844e-19	
0.05	1.194e-05	7.209e-17	2.726e-14	1.920e-19	7.261e-17	
0.06	9.463e-07	4.935e-17	3.564e-14	9.802e-20	7.078e-17	
0.08	3.663e-07	2.119e-16	2.795e-13	3.354e-19	4.423e-16	
0.1	6.185e-06	1.554e-14	2.163e-11	2.377e-17	3.309e-14	

0.15	3.859e-06	1.059e-13	8.974e-11	1.745e-16	1.478e-13
0.2	4.996e-07	7.216e-14	3.909e-11	1.274e-16	6.899e-14
0.3	9.052e-07	1.317e-12	2.907e-10	2.498e-15	5.514e-13
0.4	2.689e-06	1.998e-11	2.305e-09	3.893e-14	4.492e-12
0.5	1.121e-07	2.871e-12	2.066e-10	5.636e-15	4.056e-13
0.6	3.752e-08	2.582e-12	1.320e-10	5.040e-15	2.577e-13
0.8	1.316e-08	4.140e-12	1.231e-10	7.874e-15	2.342e-13
1.0	1.182e-10	1.166e-13	2.412e-12	2.148e-16	4.446e-15
Totals	5.779e-02	3.120e-11	3.211e-09	6.052e-14	6.196e-12

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: C:\ushield\CaseFiles\Pu-239_03_ft_01_m.ms7****Case Title: Pu-239 3 foot water****This case was run on Thursday, May 20, 2010 at 10:51:39 PM****Dose Point # 1 - (291.44,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	7.091e-011	8.537e-009
Photon Energy Fluence Rate	MeV/cm ² /sec	3.120e-011	3.211e-009
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	6.052e-014	6.196e-012
Absorbed Dose Rate in Air	mGy/hr	5.284e-016	5.409e-014
"	mrad/hr	5.284e-014	5.409e-012
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.553e-016	6.836e-014
o Opposed	"	4.943e-016	5.035e-014
o Rotational	"	4.943e-016	5.035e-014
o Isotropic	"	4.381e-016	4.475e-014
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	6.823e-016	7.070e-014
o Opposed	"	6.440e-016	6.635e-014
o Rotational	"	6.440e-016	6.635e-014
o Isotropic	"	4.687e-016	4.789e-014
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	5.708e-016	5.931e-014
o Posterior/Anterior	"	4.917e-016	5.060e-014
o Lateral	"	3.512e-016	3.562e-014
o Rotational	"	4.348e-016	4.459e-014
o Isotropic	"	3.660e-016	3.737e-014



2-Foot Stone Revetment Shielding Pu-239 MicroShield Output

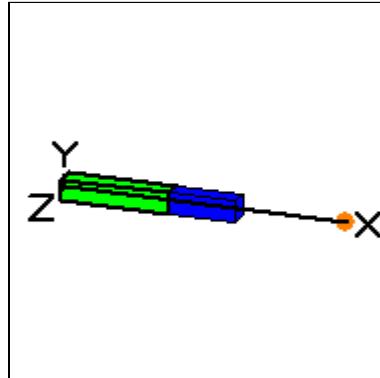
MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

Filename	Run Date	Run Time	Duration
Pu-239_02_ft_01_m.ms7	May 20, 2010	10:49:36 PM	00:00:00

Project Info	
Case Title	Pu-239 2 foot stone
Description	Pu-239 1 pCi/g sediment 2 foot armor stone shield
Geometry	16 - Infinite Slab

Source Dimensions	
Thickness	100.0 cm (3 ft 3.4 in)



Dose Points			
A	X	Y	Z
#1	260.96 cm (8 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	60.96 cm	Concrete	2.7
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices		
Number of Groups: 25		
Lower Energy Cutoff: 0.015		
Photons < 0.015: Included		
Library: ICRP-38		
Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Pu-239	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1	
Integration Parameters	

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.015	5.749e-02	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.02	2.696e-04	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.03	5.828e-08	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.04	3.308e-06	1.882e-50	1.882e-50	8.323e-53	8.323e-53
0.05	1.194e-05	7.104e-35	1.209e-33	1.892e-37	3.221e-36
0.06	9.463e-07	3.356e-29	1.335e-27	6.665e-32	2.653e-30
0.08	3.663e-07	6.805e-24	4.502e-22	1.077e-26	7.125e-25
0.1	6.185e-06	2.698e-20	3.574e-18	4.127e-23	5.468e-21

0.15	3.859e-06	5.602e-18	1.348e-15	9.225e-21	2.220e-18
0.2	4.996e-07	1.379e-17	3.575e-15	2.433e-20	6.311e-18
0.3	9.052e-07	9.261e-16	1.711e-13	1.757e-18	3.246e-16
0.4	2.689e-06	3.015e-14	3.617e-12	5.874e-17	7.048e-15
0.5	1.121e-07	7.513e-15	6.369e-13	1.475e-17	1.250e-15
0.6	3.752e-08	1.034e-14	6.507e-13	2.018e-17	1.270e-15
0.8	1.316e-08	3.128e-14	1.219e-12	5.949e-17	2.319e-15
1.0	1.182e-10	1.395e-15	3.796e-14	2.572e-18	6.997e-17
Totals	5.779e-02	8.161e-14	6.338e-12	1.575e-16	1.229e-14

MicroShield 7.02 (05-MSD-7.00-1022)
Battelle
Conversion of calculated exposure in air to dose
FILE: C:\ushield\CaseFiles\Pu-239_02_ft_01_m.ms7
Case Title: Pu-239 2 foot stone
This case was run on Thursday, May 20, 2010 at 10:49:36 PM
Dose Point # 1 - (260.96,0,0) cm

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	1.513e-013	1.356e-011
Photon Energy Fluence Rate	MeV/cm ² /sec	8.161e-014	6.338e-012
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.575e-016	1.229e-014
Absorbed Dose Rate in Air	mGy/hr	1.375e-018	1.073e-016
"	mrad/hr	1.375e-016	1.073e-014
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.664e-018	1.321e-016
o Opposed	"	1.297e-018	1.006e-016
o Rotational	"	1.297e-018	1.006e-016
o Isotropic	"	1.148e-018	8.912e-017
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.751e-018	1.379e-016
o Opposed	"	1.659e-018	1.304e-016
o Rotational	"	1.659e-018	1.304e-016
o Isotropic	"	1.228e-018	9.533e-017
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.462e-018	1.153e-016
o Posterior/Anterior	"	1.278e-018	9.975e-017
o Lateral	"	9.333e-019	7.170e-017
o Rotational	"	1.136e-018	8.835e-017
o Isotropic	"	9.630e-019	7.451e-017



Unshielded Co-60 MicroShield Output

MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

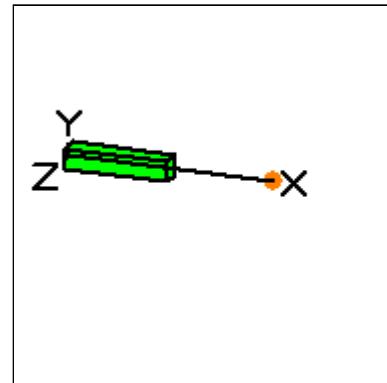
Filename	Run Date	Run Time	Duration
Co-60_00_ft_01_m.ms7	January 26, 2012	10:50:56 AM	00:00:00

Project Info

Case Title	Co-60 1 meter air
Description	Co-60 1 pCi/g sediment 1 meter air shield
Geometry	16 - Infinite Slab

Source Dimensions

Thickness	100.0 cm (3 ft 3.4 in)
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**Dose Points**

A	X	Y	Z
#1	200.0 cm (6 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices

Number of Groups: 25
 Lower Energy Cutoff: 0.015
 Photons < 0.015: Included
 Library: ICRP-38

Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Co-60	1.5000e-006	5.5500e-002

Buildup: The material reference is Source
Integration Parameters**Results**

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	6.129e-06	2.245e-09	2.281e-09	1.926e-10	1.957e-10
0.3	4.218e-06	3.691e-06	1.506e-05	7.002e-09	2.857e-08
0.8	4.218e-06	1.517e-05	4.324e-05	2.885e-08	8.224e-08
1.0	5.544e-02	2.783e-01	7.207e-01	5.131e-04	1.328e-03
1.5	5.549e-02	5.164e-01	1.114e+00	8.687e-04	1.874e-03
2.0	6.105e-07	8.822e-06	1.732e-05	1.364e-08	2.678e-08
3.0	1.998e-09	5.337e-08	9.340e-08	7.240e-11	1.267e-10
Totals	1.109e-01	7.947e-01	1.835e+00	1.382e-03	3.203e-03

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: E:\ushield\Co-60_00_ft_01.m.ms7****Case Title: Co-60 1 meter air****This case was run on Thursday, January 26, 2012 at 10:50:56 AM****Dose Point # 1 - (200,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	6.226e-001	1.464e+000
Photon Energy Fluence Rate	MeV/cm ² /sec	7.947e-001	1.835e+000
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.382e-003	3.203e-003
Absorbed Dose Rate in Air	mGy/hr	1.206e-005	2.796e-005
"	mrad/hr	1.206e-003	2.796e-003
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.372e-005	3.181e-005
o Opposed	"	1.183e-005	2.739e-005
o Rotational	"	1.183e-005	2.739e-005
o Isotropic	"	1.057e-005	2.446e-005
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.457e-005	3.382e-005
o Opposed	"	1.405e-005	3.258e-005
o Rotational	"	1.405e-005	3.258e-005
o Isotropic	"	1.117e-005	2.588e-005
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.234e-005	2.862e-005
o Posterior/Anterior	"	1.138e-005	2.635e-005
o Lateral	"	9.071e-006	2.097e-005
o Rotational	"	1.025e-005	2.374e-005
o Isotropic	"	9.077e-006	2.100e-005

3-Foot Water Shielding Co-60 MicroShield Output

MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

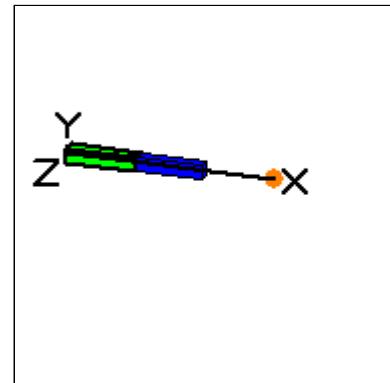
Filename	Run Date	Run Time	Duration
Co-60_03_ft_01_m.ms7	January 26, 2012	10:55:41 AM	00:00:00

Project Info

Case Title	Co-60 3 foot water
Description	Co-60 1 pCi/g sediment 3 foot water shield
Geometry	16 - Infinite Slab

Source Dimensions

Thickness	100.0 cm (3 ft 3.4 in)
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**Dose Points**

A	X	Y	Z
#1	291.44 cm (9 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	91.44 cm	Water	1
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices

Number of Groups: 25

Lower Energy Cutoff: 0.015

Photons < 0.015: Included

Library: ICRP-38

Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Co-60	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1**Integration Parameters****Results**

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	6.129e-06	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.3	4.218e-06	6.135e-12	1.355e-09	1.164e-14	2.570e-12
0.8	4.218e-06	1.327e-09	3.945e-08	2.523e-12	7.504e-11
1.0	5.544e-02	5.466e-05	1.131e-03	1.008e-07	2.085e-06
1.5	5.549e-02	3.946e-04	4.422e-03	6.640e-07	7.440e-06
2.0	6.105e-07	1.589e-08	1.239e-07	2.458e-11	1.915e-10
3.0	1.998e-09	2.727e-10	1.407e-09	3.700e-13	1.908e-12
Totals	1.109e-01	4.493e-04	5.553e-03	7.648e-07	9.525e-06

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: E:\ushield\Co-60_03_ft_01.m.ms7****Case Title: Co-60 3 foot water****This case was run on Thursday, January 26, 2012 at 10:55:41 AM****Dose Point # 1 - (291.44,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	3.178e-004	4.079e-003
Photon Energy Fluence Rate	MeV/cm ² /sec	4.493e-004	5.553e-003
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	7.648e-007	9.525e-006
Absorbed Dose Rate in Air	mGy/hr	6.676e-009	8.316e-008
"	mrad/hr	6.676e-007	8.316e-006
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	7.564e-009	9.433e-008
o Opposed	"	6.580e-009	8.180e-008
o Rotational	"	6.580e-009	8.180e-008
o Isotropic	"	5.897e-009	7.323e-008
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	8.014e-009	1.000e-007
o Opposed	"	7.749e-009	9.663e-008
o Rotational	"	7.749e-009	9.663e-008
o Isotropic	"	6.213e-009	7.726e-008
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	6.816e-009	8.496e-008
o Posterior/Anterior	"	6.316e-009	7.858e-008
o Lateral	"	5.089e-009	6.308e-008
o Rotational	"	5.701e-009	7.088e-008
o Isotropic	"	5.076e-009	6.299e-008



MicroShield 7.02
Battelle (05-MSD-7.00-1022)

Date	By	Checked

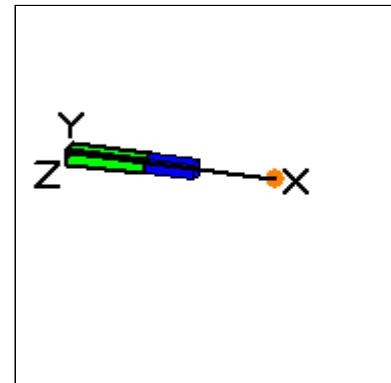
Filename	Run Date	Run Time	Duration
Co-60_02_ft_01_m.ms7	January 26, 2012	10:53:49 AM	00:00:00

Project Info

Case Title	Co-60 2 foot stone
Description	Co-60 1 pCi/g sediment 2 foot armor stone shield
Geometry	16 - Infinite Slab

Source Dimensions

Thickness	100.0 cm (3 ft 3.4 in)
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**Dose Points**

A	X	Y	Z
#1	260.96 cm (8 ft 6.7 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Source	Infinite	Concrete	1.5
Shield 1	60.96 cm	Concrete	2.7
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices

Number of Groups: 25

Lower Energy Cutoff: 0.015

Photons < 0.015: Included

Library: ICRP-38

Nuclide	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Co-60	1.5000e-006	5.5500e-002

Buildup: The material reference is Shield 1**Integration Parameters****Results**

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	6.129e-06	0.000e+00	0.000e+00	0.000e+00	0.000e+00
0.3	4.218e-06	4.315e-15	7.973e-13	8.186e-18	1.512e-15
0.8	4.218e-06	1.002e-11	3.907e-10	1.906e-14	7.432e-13
1.0	5.544e-02	6.544e-07	1.780e-05	1.206e-09	3.282e-08
1.5	5.549e-02	1.004e-05	1.493e-04	1.689e-08	2.511e-07
2.0	6.105e-07	6.264e-10	6.590e-09	9.686e-13	1.019e-11
3.0	1.998e-09	1.729e-11	1.200e-10	2.346e-14	1.628e-13
Totals	1.109e-01	1.069e-05	1.671e-04	1.809e-08	2.840e-07

MicroShield 7.02 (05-MSD-7.00-1022)**Battelle****Conversion of calculated exposure in air to dose****FILE: E:\ushield\Co-60_02_ft_01_m.ms7****Case Title: Co-60 2 foot stone****This case was run on Thursday, January 26, 2012 at 10:53:49 AM****Dose Point # 1 - (260.96,0,0) cm**

<u>Results (Summed over energies)</u>	<u>Units</u>	<u>Without Buildup</u>	<u>With Buildup</u>
Photon Fluence Rate (flux)	Photons/cm ² /sec	7.345e-006	1.173e-004
Photon Energy Fluence Rate	MeV/cm ² /sec	1.069e-005	1.671e-004
Exposure and Dose Rates:			
Exposure Rate in Air	mR/hr	1.809e-008	2.840e-007
Absorbed Dose Rate in Air	mGy/hr	1.579e-010	2.479e-009
"	mrad/hr	1.579e-008	2.479e-007
Deep Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.788e-010	2.808e-009
o Opposed	"	1.559e-010	2.444e-009
o Rotational	"	1.559e-010	2.444e-009
o Isotropic	"	1.398e-010	2.191e-009
Shallow Dose Equivalent Rate	(ICRP 51 - 1987)		
o Parallel Geometry	mSv/hr	1.893e-010	2.974e-009
o Opposed	"	1.831e-010	2.877e-009
o Rotational	"	1.831e-010	2.877e-009
o Isotropic	"	1.472e-010	2.308e-009
Effective Dose Equivalent Rate	(ICRP 51 - 1987)		
o Anterior/Posterior Geometry	mSv/hr	1.611e-010	2.530e-009
o Posterior/Anterior	"	1.496e-010	2.346e-009
o Lateral	"	1.208e-010	1.892e-009
o Rotational	"	1.351e-010	2.118e-009
o Isotropic	"	1.204e-010	1.886e-009

Attachment 2
Risk-Based Concentrations for Radionuclides of Concern

Risk-Based Concentrations for Radionuclides of Concern
Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard,
San Francisco, California

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EXHIBIT

- 1 RBC Equations

Table 1

Comparison of RBC + Background Concentrations for ROCs to Maximum Detected ROC Concentrations

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

Exposure Scenario	ROC	Background Concentration (pCi/g)	RBC ^(a) + Background Concentration (pCi/g)	Maximum Detected Concentration (pCi/g)	Maximum Detection Exceeds RBC + Background?
Intertidal	Cs-137	0.0747	0.92	0.248	N
	Co-60	0.0426	0.50	0.0452	N
	Pu-239	0.0173	36.77	0.0422	N
	Ra-226	0.6039	1.6039	1.06	N
	Sr-90	0.1747	6.27	4.56	N
	U-235	0.2342	2.92	0.672	N
Subtidal	Cs-137	0.0747	256.06	0.245	N
	Co-60	0.0426	121.77	0.0884	N
	Pu-239	0.0173	36.95	0.753	N
	Ra-226	0.6039	9.48	1.38	N
	Sr-90	0.1747	6.63	0.759	N
	U-235	0.2342	57.77	0.697	N

Notes:

a Tables 8 and 9 summarize the RBCs. RBCs were calculated using equations provided in the USEPA (2016) PRG calculator for radionuclides, modified to include the shellfish consumption pathway (see Exhibit 1 for equations). The RBCs incorporate slope factors provided in USEPA (2016), the USEPA (2016) equations for recreational adult and child exposure to soil from incidental ingestion and external exposure, the Parcel F approach for adult shellfish consumption (Battelle and Sea Engineering, 2013; ITSI & Gilbane, 2013), and the Parcel F exposure assumptions for recreational exposure (Battelle and Sea Engineering, 2013; ITSI & Gilbane, 2013).

The intertidal RBC for Ra-226 is less than the background concentration for Ra-226. The terrestrial soil PAL of 1 pCi/g is used as the Ra-226 RBC for intertidal sediments, consistent with the approach in Battelle and Sea Engineering (2013) and ITSI & Gilbane (2013).

PAL project action limit
 pCi/g picocurie per gram
 PRG preliminary remediation goal
 RBC risk-based concentration
 ROC radionuclide of concern

References:

Battelle and Sea Engineering, Inc. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2a at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. April.

ITSI Gilbane & SAIC. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2b at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. September.

United States Environmental Protection Agency (USEPA). 2016. Preliminary Remediation Goals (PRG) Calculator for Radionuclides. Accessed October 6. https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search

TABLE 2

Exposure Assumptions

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

Exposure Medium	Exposure Route	Receptor Population	Receptor Age	Parameter	Parameter Definition	Value	Units	Reference
Sediment	Ingestion	Recreational User	Adult and Child	IRS _{rec-a}	Adult Ingestion Rate – Sediment	100	mg/day	ITSI Gilbane & SAIC, 2013. Table 2-1.
				IRS _{rec-c}	Child Ingestion Rate – Sediment	200	mg/day	USEPA, 2014 and 2016
				IFS _{rec-adj}	Age-Adjusted Ingestion Fraction – Sediment	83,200	mg	Calculated - see Exhibit 1.
				EF _{rec-a}	Adult Exposure Frequency	26	days/year	ITSI Gilbane & SAIC, 2013. Table 2-1.
				EF _{rec-c}	Child Exposure Frequency	26	days/year	ITSI Gilbane & SAIC, 2013. Table 2-1.
				ED _{rec-a}	Adult Exposure Duration	20	years	USEPA, 2014 and 2016 (a).
				ED _{rec-c}	Child Exposure Duration	6	years	USEPA, 2014 and 2016 (a).
				t _{rec}	Time – Recreational User	26	years	ITSI Gilbane & SAIC, 2013. Table 2-1.
	External Exposure	Recreational User	Adult and Child	ET _{rec}	Exposure Time	8	hours/day	ITSI Gilbane & SAIC, 2013. Table 2-1.
				EF _{rec}	Exposure Frequency	26	days/year	ITSI Gilbane & SAIC, 2013. Table 2-1.
				ED _{rec}	Exposure Duration	26	years	USEPA, 2014 and 2016 (a).
				t _{rec}	Time – Recreational User	26	years	ITSI Gilbane & SAIC, 2013. Table 2-1.
				ACF _{ext-sv}	Area Correction Factor	1	unitless	USEPA, 2016. Based on a site area of 1,000,000 square meters.
Shellfish	Ingestion	Recreational User	Adult	IRSFISH _{rec-a}	Adult Ingestion Rate – Shellfish	2.13	grams/day	ITSI Gilbane & SAIC, 2013. Table 2-1.
				FI _{sfish}	Fraction Ingested from Contaminated Source	0.1	unitless	ITSI Gilbane & SAIC, 2013. Table 2-1.
				EF _{rec-a-sfish}	Exposure Frequency	365	days/year	Barajas & Associates, Inc., 2008. Table 2-1.
				t _{rec-a}	Time – Recreational User	20	years	ITSI Gilbane & SAIC, 2013. Table 2-1.

Notes:

a A residential exposure duration was used to evaluate recreational users (ITSI Gilbane & SAIC, 2013). The exposure duration was revised based on the USEPA (2014, 2016) recommended default exposure duration for residential exposure (20 years for an adult plus 6 years for a child).

b Children under the age of six years were assumed not to consume shellfish (ITSI Gilbane & SAIC, 2013). The exposure duration was revised based on the USEPA (2014, 2016) total default residential exposure duration of 26 years, less the USEPA (2016) default exposure duration for children of 6 years.

mg milligram

mg/day milligram per day

References:

Barajas & Associates, Inc. (Barajas). 2008. Final Feasibility Study Report for Parcel F, Hunters Point Shipyard, San Francisco, California. April 30.

ITSI Gilbane & SAIC. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2b at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. September.

United States Environmental Protection Agency (USEPA). 2014. Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors. Office of Solid Waste and Emergency Response.

United States Environmental Protection Agency (USEPA). 2016. Preliminary Remediation Goals (PRG) Calculator for Radionuclides. Accessed October 6. https://epa-prgs.ornl.gov/cgi-bin/radionuclides/prg_search

Table 3

Slope Factors and Isotope-Specific Information

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	Half-life ^a (years)	λ^a (1/years)	Food Ingestion Slope Factor (SF _{food}) ^a (risk/pCi)	Soil Ingestion Slope Factor (SF _s) ^a (risk/pCi)	External Slope Factor (SF _{ext-sv}) ^a (risk/pCi)	K _d Distribution Coefficient ^{b,c} (L/kg)	Mollusk Bioconcentration Factor (MCF) ^{b,c} (pCi/kg per pCi/L)	Intertidal Gamma Shielding Factor (GSF _{int-ext-sv}) ^{b,c} (unitless)	Subtidal Gamma Shielding Factor (GSF _{sub-ext-sv}) ^{b,c} (unitless)
Cs-137	3.02E+01	2.30E-02	3.74E-11	4.26E-11	2.53E-06	4,000	60	1.00E+00	4.59E-04
Co-60	5.27E+00	1.31E-01	2.23E-11	3.81E-11	1.24E-05	300,000	20,000	1.00E+00	2.99E-03
Pu-239	2.41E+04	2.87E-05	1.74E-10	2.28E-10	2.09E-10	100,000	3,000	1.00E+00	5.84E-05
Ra-226	1.60E+03	4.33E-04	5.14E-10	6.77E-10	8.37E-06	2,000	100	1.00E+00	3.29E-03
Sr-90	2.88E+01	2.41E-02	9.51E-11	1.35E-10	1.95E-08	8	10	1.00E+00	8.05E-32
U-235	7.04E+08	9.84E-10	9.77E-11	1.54E-10	5.76E-07	1,000	30	1.00E+00	3.31E-05

Notes:

a. United States Environmental Protection Agency. Preliminary Remediation Goals for Radionuclides (PRG). October 26, 2016. <https://epa-prgs.ornl.gov/radionuclides/download.html>

b. Battelle and Sea Engineering, Inc. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2a at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. April.

c. ITSI Gilbane & SAIC. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2b at Parcel F, Hunters Point Naval Shipyard, San Francisco, California.

ROC	radionuclide of concern	pCi/L	picocurie per liter
L/kg	liter per kilogram	risk/pCi	risk per picocurie
pCi/kg	picocurie per kilogram	ROC	radionuclide of concern

Table 4

RBCs for Shellfish Consumption – Intertidal and Subtidal Scenarios

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	Food Ingestion Slope Factor (SF_{food}^a) (risk/pCi)	K_d Distribution Coefficient ^a (L/kg)	Mollusk Bioconcentration Factor (MCF) ^a (pCi/kg per pCi/L)	Half-life ^a (years)	λ^a (1/years)	$1 - e^{-\lambda t_{rec-a}}$	$RBC_{rec-sed-sfish}^b$ (pCi/g)
Cs-137	3.74E-11	4,000	60	3.02E+01	2.30E-02	3.69E-01	1.43E+03
Co-60	2.23E-11	300,000	20,000	5.27E+00	1.31E-01	9.27E-01	1.22E+03
Pu-239	1.74E-10	100,000	3,000	2.41E+04	2.87E-05	5.74E-04	1.23E+02
Ra-226	5.14E-10	2,000	100	1.60E+03	4.33E-04	8.62E-03	2.51E+01
Sr-90	9.51E-11	8	10	2.88E+01	2.41E-02	3.82E-01	6.82E+00
U-235	9.77E-11	1,000	30	7.04E+08	9.84E-10	1.97E-08	2.19E+02

Notes:

a. See Table 3 for sources of slope factors and isotope-specific values.

b. See Exhibit 1 for RBC equations. Exposure assumptions are provided in Table 2.

L/kg liter per kilogram
 pCi/g picocurie per gram
 pCi/kg picocurie per kilogram
 pCi/L picocurie per liter

RBC risk-based concentration
 risk/pCi risk per picocurie
 ROC radionuclide of concern

Table 5

RBCs for Incidental Soil Ingestion – Intertidal and Subtidal Scenarios

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	Soil Ingestion Slope Factor (SF_s) ^a (risk/pCi)	Half-life ^a (years)	λ^a (1/years)	$1 - e^{-\lambda t_{rec}}$	RBC _{rec-sed-ing} ^b (pCi/g)
Cs-137	4.26E-11	3.02E+01	2.30E-02	4.50E-01	3.75E+02
Co-60	3.81E-11	5.27E+00	1.31E-01	9.67E-01	1.11E+03
Pu-239	2.28E-10	2.41E+04	2.87E-05	7.46E-04	5.27E+01
Ra-226	6.77E-10	1.60E+03	4.33E-04	1.12E-02	1.79E+01
Sr-90	1.35E-10	2.88E+01	2.41E-02	4.66E-01	1.20E+02
U-235	1.54E-10	7.04E+08	9.84E-10	2.56E-08	7.80E+01

Notes:

a. Sources for slope factors and isotope-specific information are provided in Table 3.

b. See Exhibit 1 for RBC equations. Exposure assumptions are provided in Table 2.

pCi/g picocurie per gram
 RBC risk-based concentration
 risk/pCi risk per picocurie
 ROC radionuclide of concern

Table 6

RBCs for External Exposure – Intertidal Scenario

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	External Slope Factor (SF _{ext-sv}) ^a (risk/pCi)	Half-life ^a (years)	λ^a (1/years)	$1 - e^{-\lambda t_{rec}}$	Intertidal Gamma Shielding Factor (GSF _{int-ext-sv}) ^a (unitless)	RBC _{rec-sed-ext-int} ^b (pCi/g)
Cs-137	2.53E-06	3.02E+01	2.30E-02	4.50E-01	1.00E+00	8.51E-01
Co-60	1.24E-05	5.27E+00	1.31E-01	9.67E-01	1.00E+00	4.60E-01
Pu-239	2.09E-10	2.41E+04	2.87E-05	7.46E-04	1.00E+00	7.75E+03
Ra-226	8.37E-06	1.60E+03	4.33E-04	1.12E-02	1.00E+00	1.95E-01
Sr-90	1.95E-08	2.88E+01	2.41E-02	4.66E-01	1.00E+00	1.12E+02
U-235	5.76E-07	7.04E+08	9.84E-10	2.56E-08	1.00E+00	2.81E+00

Notes:

a. Sources for slope factors and isotope-specific information are provided in Table 3.

b. See Exhibit 1 for RBC equations. Exposure assumptions are provided in Table 2.

pCi/g picocurie per gram
 RBC risk-based concentration
 risk/pCi risk per picocurie
 ROC radionuclide of concern

Table 7

RBCs for External Exposure – Subtidal Scenario

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	External Slope Factor (SF _{ext-sv}) ^a (risk/pCi)	Half-life ^a (years)	λ^a (1/years)	$1 - e^{-\lambda t_{rec}}$	Subtidal Gamma Shielding Factor (GSF _{sub-ext-sv}) ^a (unitless)	RBC _{rec-sed-ext-sub} ^b (pCi/g)
Cs-137	2.53E-06	3.02E+01	2.30E-02	4.50E-01	4.59E-04	1.85E+03
Co-60	1.24E-05	5.27E+00	1.31E-01	9.67E-01	2.99E-03	1.54E+02
Pu-239	2.09E-10	2.41E+04	2.87E-05	7.46E-04	5.84E-05	1.33E+08
Ra-226	8.37E-06	1.60E+03	4.33E-04	1.12E-02	3.29E-03	5.92E+01
Sr-90	1.95E-08	2.88E+01	2.41E-02	4.66E-01	8.05E-32	1.39E+33
U-235	5.76E-07	7.04E+08	9.84E-10	2.56E-08	3.31E-05	8.50E+04

Notes:

a. Sources for slope factors and isotope-specific information are provided in Table 3.

b. See Exhibit 1 for RBC equations. Exposure assumptions are provided in Table 2.

pCi/g picocurie per gram
 RBC risk-based concentration
 risk/pCi risk per picocurie
 ROC radionuclide of concern

Table 8

Updated Multi-pathway RBCs – Intertidal Scenario

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	Slope Factors and Isotope-Specific Information					Carcinogenic Target Risk (TR) = 1×10^{-6}			
	Half-life ^a (years)	λ^a (1/years)	Food Ingestion Slope Factor (SF _{food}) ^a (risk/pCi)	Soil Ingestion Slope Factor (SF _s) ^a (risk/pCi)	External Slope Factor (SF _{ext-sv}) ^a (risk/pCi)	RBC _{rec-sed-fish} ^b (pCi/g)	RBC _{rec-sed-ing} ^b (pCi/g)	RBC _{rec-sed-ext-int} ^b (pCi/g)	RBC _{rec-sed-int-tot} ^{b,c} (pCi/g)
Cs-137	3.02E+01	2.30E-02	3.74E-11	4.26E-11	2.53E-06	1.43E+03	3.75E+02	8.51E-01	8.48E-01
Co-60	5.27E+00	1.31E-01	2.23E-11	3.81E-11	1.24E-05	1.22E+03	1.11E+03	4.60E-01	4.60E-01
Pu-239	2.41E+04	2.87E-05	1.74E-10	2.28E-10	2.09E-10	1.23E+02	5.27E+01	7.75E+03	3.68E+01
Ra-226	1.60E+03	4.33E-04	5.14E-10	6.77E-10	8.37E-06	2.51E+01	1.79E+01	1.95E-01	1.91E-01
Sr-90	2.88E+01	2.41E-02	9.51E-11	1.35E-10	1.95E-08	6.82E+00	1.20E+02	1.12E+02	6.10E+00
U-235	7.04E+08	9.84E-10	9.77E-11	1.54E-10	5.76E-07	2.19E+02	7.80E+01	2.81E+00	2.68E+00

Notes:

a. Sources for slope factors and isotope-specific information are provided in Table 3.

b. See Exhibit 1 for RBC equations. Exposure assumptions are provided in Table 2.

c. The RBCs in this column are the multi-pathway, intertidal scenario RBCs for shellfish consumption, sediment ingestion, and external exposure.

pCi/g picocurie per gram
 RBC risk-based concentration
 risk/pCi risk per picocurie
 ROC radionuclide of concern

Table 9

Updated Multi-pathway RBCs – Subtidal Scenario

Addendum to the Feasibility Study Report for Parcel F, Hunters Point Naval Shipyard, San Francisco, California

ROC	Slope Factors and Isotope-Specific Information					Carcinogenic Target Risk (TR) = 1×10^{-6}			
	Half-life ^a (years)	λ^a (1/years)	Food Ingestion Slope Factor (SF _{food}) ^a (risk/pCi)	Soil Ingestion Slope Factor (SF _s) ^a (risk/pCi)	External Slope Factor (SF _{ext-sv}) ^a (risk/pCi)	RBC _{rec-sed-fish} ^b (pCi/g)	RBC _{rec-sed-ing} ^b (pCi/g)	RBC _{rec-sed-ext-sub} ^b (pCi/g)	RBC _{rec-sed-sub-tot} ^{b,c} (pCi/g)
Cs-137	3.02E+01	2.30E-02	3.74E-11	4.26E-11	2.53E-06	1.43E+03	3.75E+02	1.85E+03	2.56E+02
Co-60	5.27E+00	1.31E-01	2.23E-11	3.81E-11	1.24E-05	1.22E+03	1.11E+03	1.54E+02	1.22E+02
Pu-239	2.41E+04	2.87E-05	1.74E-10	2.28E-10	2.09E-10	1.23E+02	5.27E+01	1.33E+08	3.69E+01
Ra-226	1.60E+03	4.33E-04	5.14E-10	6.77E-10	8.37E-06	2.51E+01	1.79E+01	5.92E+01	8.87E+00
Sr-90	2.88E+01	2.41E-02	9.51E-11	1.35E-10	1.95E-08	6.82E+00	1.20E+02	1.39E+33	6.45E+00
U-235	7.04E+08	9.84E-10	9.77E-11	1.54E-10	5.76E-07	2.19E+02	7.80E+01	8.50E+04	5.75E+01

Notes:

a. Sources for slope factors and isotope-specific information are provided in Table 3.

b. See Exhibit 1 for RBC equations. Exposure assumptions are provided in Table 2.

c. The RBCs in this column are the multi-pathway, subtidal scenario RBCs for shellfish consumption, sediment ingestion, and external exposure.

pCi/g picocurie per gram
 RBC risk-based concentration
 risk/pCi risk per picocurie
 ROC radionuclide of concern

EXHIBIT 1. RBC EQUATIONS

Equation 1. RBC for Shellfish Consumption – Intertidal and Subtidal Scenario^a

$$RBC_{rec-sed-sfish} (pCi/g) = \frac{TR (1 \times 10^{-6}) \times K_d \left(\frac{L}{kg} \right) \times \lambda \left(\frac{1}{years} \right)}{SF_{food} \left(\frac{risk}{pCi} \right) \times EF_{rec-a-sfish} \left(\frac{days}{year} \right) \times IRSFISH_{rec-a} \left(\frac{grams}{day} \right)} \\ \times FI_{sfish} \times MCF \left(\frac{pCi/kg}{pCi/L} \right) \times (1 - e^{-\lambda t_{rec-a}})$$

Equation 2. RBC for Incidental Soil Ingestion – Intertidal and Subtidal Scenario^b

$$RBC_{rec-sed-ing} (pCi/g) = \frac{TR (1 \times 10^{-6}) \times t_{rec} (years) \times \lambda \left(\frac{1}{years} \right)}{(1 - e^{-\lambda t_{rec}}) \times SF_s \left(\frac{risk}{pCi} \right) \times IFS_{rec-adj} (mg) \times \left(\frac{g}{1000 mg} \right)}$$

where:

$$IFS_{rec-adj} (mg) = \left(\begin{array}{l} \left(EF_{rec-c} \left(\frac{days}{year} \right) \times ED_{rec-c} (years) \times IRS_{rec-c} \left(\frac{100 mg}{day} \right) \right) + \\ \left(EF_{rec-a} \left(\frac{days}{year} \right) \times ED_{rec-a} (years) \times IRS_{rec-a} \left(\frac{100 mg}{day} \right) \right) \end{array} \right)$$

Equation 3. RBC for External Exposure – Intertidal Scenario^b

$$RBC_{rec-sed-ext-int} (pCi/g) = \frac{TR (1 \times 10^{-6}) \times t_{rec} (years) \times \lambda \frac{1}{years}}{(1 - e^{\lambda t_{rec}}) \times SF_{ext-sv} \left(\frac{risk/year}{pCi/g} \right) \times EF_{rec} \left(\frac{days}{year} \right) \times \left(\frac{1 year}{365 days} \right) \times \\ ED_{rec} (years) \times ACF_{ext-sv} (1.0 [unitless]) \times ET_{rec} \frac{hours}{day} \times \frac{1 day}{24 hours} \times GSF_{int-ext-sv} (1.0 [unitless])}$$

Equation 4. PAL for External Exposure – Subtidal Scenario^b

$$RBC_{rec-sed-ext-sub} (pCi/g) = \frac{TR (1 \times 10^{-6}) \times t_{rec} (years) \times \lambda \frac{1}{years}}{(1 - e^{\lambda t_{rec}}) \times SF_{ext-sv} \left(\frac{risk/year}{pCi/g} \right) \times EF_{rec} \left(\frac{days}{year} \right) \times \left(\frac{1 year}{365 days} \right) \times \\ ED_{rec} (years) \times ACF_{ext-sv} (1.0 [unitless]) \times ET_{rec} \frac{hours}{day} \times \frac{1 day}{24 hours} \times GSF_{sub-ext-sv} (unitless)}$$

EXHIBIT 1. RBC EQUATIONS, continued

Equation 5. Multi-pathway RBC – Intertidal Scenario^c

$$RBC_{rec-sed-int-tot} \text{ (pCi/g)} = \frac{1}{\frac{1}{RBC_{rec-sed-sfish}} + \frac{1}{RBC_{rec-sed-ing}} + \frac{1}{RBC_{rec-sed-ext-int}}}$$

Equation 6. Multi-pathway RBC – Subtidal Scenario^c

$$RBC_{rec-sed-sub-tot} \text{ (pCi/g)} = \frac{1}{\frac{1}{RBC_{rec-sed-sfish}} + \frac{1}{RBC_{rec-sed-ing}} + \frac{1}{RBC_{rec-sed-ext-sub}}}$$

Notes:

^a Equation 1 taken from Battelle and Sea Engineering (2013) and ITSI & Gilbane (2013).

^b Equations 2 through 4 taken from USEPA (2016).

^c Equations 5 and 6 adapted from USEPA (2016).

See Table 2 for exposure assumptions.

See Table 3 for slope factors and isotope-specific information.

g = gram

L/kg = liter per kilogram

mg = milligram

pCi/g = picocurie per gram

RBC = risk-based concentration

risk/pCi = risk per picocurie

TR = target cancer risk

References:

Battelle and Sea Engineering, Inc. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2a at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. April.

ITSI Gilbane & SAIC. 2013. Final Technical Memorandum for Radiological Data Gap Investigation Phase 2b at Parcel F, Hunters Point Naval Shipyard, San Francisco, California. September.

United States Environmental Protection Agency (USEPA). 2016. Preliminary Remediation Goals (PRG) Calculator for Radionuclides. Accessed October 6. <https://epa-prgs.ornl.gov/radionuclides/equations.html>